Quarterly Report
Third Quarter 1995
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A. Task Objective: Algorithm Development for Global Mapping of Phycoerythrin Pigment, Dissolved Organic Matter, and Chlorophyllous Pigment

1. MODIS North Atlantic Test Site Establishment and Characterization

As previously reported, the MODIS North Atlantic Test Site has been established as originally proposed. The Test Site includes the New York Bight/Mid-Atlantic Bight/Gulf Stream/Sargasso Sea and is conveniently located north and east of GSFC/WFF. Characterization has been initiated by ship sampling, aircraft overflights, and analysis of historical data available from within the NASA AOL project since 1980. Much of the data obtained in the northwestern portion of the test site will be used for algorithm development in Case 2 waters.

a. During this 3-month reporting period no airborne missions were flown in the MODIS Test Site but several are planned for the first quarter of 1996 (February and March) in conjunction with the Department of Energy Ocean Margins Program (OMP) in conjunction with ship cruises led by Woods Hole scientists Dr. Daniel Repeta. This airborne mission (and preliminary test flights) will allow further development of the phycoerythrin pigment algorithm. It will also provide additional evaluation of the recently-rebuilt AOL system and will provide data needed to further calibrate the fluorescence/Raman ratios derived from the AOL spectrometer data to retrieve CDOM and chlorophyll absorption coefficients.

A manuscript describing some of the chromophoric dissolved organic matter (DOM) retrieval needed for the phycoerythrin algorithm work was published during a previous reporting period. The reader should consult this paper for details of the progress of the DOM retrieval using fluorescence methods. The paper is: Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Airborne Laser Spectral Fluorescence Measurements by Frank E. Hoge, Anthony Vodacek, Robert N. Swift and James K. Yungel, Applied Optics 34, 7032-7038 (1995). The CDOM and the chlorophyll absorption must be satisfactorily modeled and retrieved before the weakly-absorbing phycoerythrin can be retrieved.

Other Data Acquisition for Algorithm Development

During July 1995 airborne active-passive ocean color data was obtained over the Arabian Sea during participation in the NSF/ONR Arabian Sea Experiment. Data was also taken over the Mediterrean Sea during transit to Oman where the Arabian Sea flights will be staged. Considerable Case 1 and Case 2 ocean color data is expected during these JGOFS flights both during the mapping flights over the Research Vessel Thompson and during the transit flights. Flights over the MAB in April 1995 served as test flights for the Arabian Sea experiments.

The above airborne flights allowed further evaluation of a new 256 channel ocean color spectrometer designed and built at Wallops Flight Facility. It was found that the color sensor possessed the requisite sensitivity for ocean color spectra in a high-rate/low-integration-time mode needed to allow editing of data containing sun glint. The prototype sensor was successfully flown during the JGOFS Iron Enrichment Experiments off the coast of Ecuador in November

1993. A still higher sensitivity detector and higher resolution sensor was successfully flown in March 1995 and during the JGOFS Arabian Sea Experiment. Preliminary evaluation of the data suggests that it is of good quality.

The evaluation of a sea surface temperature sensor manufactured by Heimann/EG&G was successfully continued from the previous two reporting periods. Our evaluation of this sensor suggests that the precision is satisfactory for support of the validation of MODIS products and algorithms relative to sea surface temperature.

2. Selection of Case 1 Data Sets.

As given in a prior report, airborne active-passive ocean color data acquired within the MODIS Test Site with the NASA Airborne Oceanographic Lidar are continually being screened for use in algorithm development. The AOL active-passive data in the Middle Atlantic Bight (MAB) during April 1994 and 1995 displayed remarkable quality and is the primary basis of the phycoerythrin retrieval by model inversion.

Other data sets are also under evaluation. Included in this evaluation are satellite CZCS data in the Middle Atlantic Bight. This data is the only known satellite data of satisfactory quality for testing the MODIS portions of the phycoerythrin algorithm that require concurrent CDOM and chlorophyll retrievals.

B. Other Work Accomplished

1. Ship Data.

As reported in previously published papers, recovery of the absorption coefficients for the light-absorbing or chromophoric components of the dissolved organic matter (aCDOM) from their
fluorescence emission has been established by laboratory analyses of surface samples gathered from several ship cruises. These absorbance and fluorescence analyses, (and work reported by others), show that absorption coefficients in the near ultraviolet can be directly retrieved from measurements of the fluorescence emission of CDOM. Thus, absorption coefficients in the entire
visible spectrum can be obtained since the CDOM absorption is rather faithfully represented as a exponential function of wavelength. The errors in the laboratory fluorescence measurements were minimized through the combined use of water Raman scatter as an internal radiometric standard and a quinine sulfate solution as a reference. This methodology reduces aCDOM algorithm retrieval errors (reported by other researchers) primarily attributable to the use of commercial spectrophotometers having maximum optical path lengths of 10 cm.

2. In Situ Optical Characterization of the MODIS North Atlantic Test Site.

The continued characterization of the Test Site is partially described in the previously mentioned publications.

A. As briefly mentioned in a previous Report, cooperative overflights within the MODIS Test Site were conducted during March/April 1995 in conjunction with shipboard CDOM sampling activity conducted by Dr. Richard Geider (Univ. Del.) and the cooperative efforts of MODIS Interdisciplinary Investigator, Dr. Niel Blough (Univ. MD). We expect to obtain flow cytometry data from Dr. William Li of the Bedford Institute of Oceanography (Canada) and HPLC data from U. Md. Horn point Environmental laboratory.

1. Phycoerythrin Algorithm Development Activities

Plans call for us to again directly address the quantification of the phycoerythrin signal as outlined in the original MODIS proposal. The phycoerythrin retrieval is being dealt with by inversion of ocean radiance models. Details of the phycoerythrin retrieval appear in the ATBD as submitted the project office. Portions of the retrieval algorithm have been tested with airborne and satellite data (see: 1. Hoge, F.E., M.E. Williams, R.N. Swift, J.K. Yungel, and A. Vodacek, Satellite retrieval of the absorption coefficient of chromphoric dissolved organic matter in continental margins, Jour. Geophys. Res., in press, 1995; 2. Hoge, Frank E., Robert N. Swift, and James K. Yungel, Oceanic radiance model development and validation: Application of airborne active-passive ocean color spectral measurements, Applied Optics, 34, 3468-3476, (1995). 3. Hoge, Frank E., Anthony Vodacek, Robert N. Swift, James Y. Yungel, Neil V. Blough, Inherent optical properties of the ocean: Retrieval of the absorption coefficient of chromophoric dissolved organic matter from airborne laser spectral fluorescence measurements, Applied Optics, 34, 7032-7038, 1995.)

2. Chlorophyll Pigment and CDOM Corrections to the Phycoerythrin Algorithm.

As previoulsy reported, major perturbations or influence to the ocean color spectrum are provided by chlorophyll and CDOM. These oceanic constituents significantly impede the retrieval of phycoerythrin pigment from the upwelled radiances. Accordingly, they must be dealt with in a systematic way in order to understand their effects and the impact on the retrieval of phycoerythrin and its ultimate quantification. In situ and airborne data gathered to date will be used to model the effects and to ascertain the extent to which they can be quantified and removed. Recently published chlorophyllous pigment models are being used to estimate the pigment absorption. Our own CDOM model is being used for recovery of chromophoric dissolved organic matter. Finally, the literature is being surveyed for the best available detritus absorption model. The most pressing modeling problem is the availability of suitable chlorophyllous and nonchlorophyllous particulate backscatter models. This problem is being addressed by : (1) closer interaction with researchers from the Stanford Research Institute (Dr. Robert Maffione) and the Johns Hopkins University / Applied Physics Laboratory (Dr. Jeff Smart
and Dr. Daniel Ondercin). These institutions are leaders in the measurement of oceanic particulate
backscatter. Data is now being transferred from JHU/APL for analysis. The SRI backscatter sensor is to be deployed during future ship cruises being overflown by the NASA/AOL active-passive system.

3. Other Data Acquisition for Algorithm Development

At the conclusion of the cooperative flights in April 1995, additional MODIS test flights
were conducted in early June 1995 in the MODIS Test Site to prepare for airborne missions during the JGOFS Arabian Sea Experiment in July 1995. Excellent data were obtained over the Arabian Sea and it is now being evaluated for application to the phycoerythrin algorithm development.

C. Anticipated Activities During Next Quarter.

1. The fourth quarter will be utilized to analyse previously obtained airborne data for advancing the phycoerythrin algorithm.

2. For the first quarter of 1996, preparations are being made to participate in the DOE OMP field experiment in the Middle Atlantic Bight in February and March 1995.

D. Other Concerns

As previously reported, RTOP funds from HQ provide the foundation support of the AOL instrumentation. The anticipated reduction of these funds will severely hamper the MODIS efforts
herein, especially validation planning and eventual field execution efforts.

The good news continues to be: Recent studies of available radiance (and reflectance) models, suggests that the retrieval of the phycoerythrin pigment at the absorption peaks of 495nm (phycourobilin, PUB) and 545nm (phycoerythrobilin, PEB) can be achieved using the 490nm and 555nm MODIS bands. Such retrievals will require a highly accurate model to account for the significant amounts of chlorophyll and DOM absorption occurring simultaneously with the phycoerythrin absorptions. The details of the phycoerythrin retrieval have been recently detailed in the ATBD.